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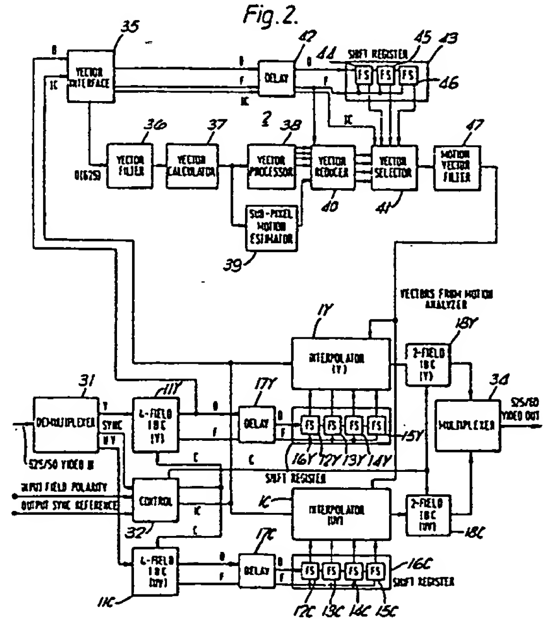
(54) Motion vector processing in digital television images.

(57) A television standards converter comprises a motion analyzer (36 to 40) for analyzing the motion between consecutive fields of an input television signal of one television standard and for deriving motion vectors in dependence on the motion, a filter (47) for recursively filtering the motion vectors, and an interpolator (1) for aligning the fields in dependence on the filtered motion vectors so as effectively to represent static pictures, and means (1) to effect conversion using the static pictures to derive the required output television signal of a different television standard.

Fig.2.



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MOTION VECTOR PROCESSING IN DIGITAL TELEVISION IMAGES

This invention relates to motion vector processing in digital television images. Such processing is used in television standards converters and in slow motion processors.

International television programme exchange necessitates standards converters due to the different television standards used in different countries, for example, the 625-line 50-fields per second (625/50) PAL system used in the UK, and the 525-line 60-fields per second (525/60) NTSC system used in the USA.

Many different standards converters have been previously proposed. One of the best known is the ACE (Advanced Conversion Equipment) developed by the British Broadcasting Corporation. Basically ACE operates on an input digital television signal line-by-line to derive interpolated samples required to form an output digital television signal. Interpolation is done not only spatially using four successive horizontal scan lines of the input television signal, but also temporally using four successive fields of the input television signal. Thus, each line of the output television signal is derived by multiplying respective samples from sixteen lines of the input television signal by respective weighting coefficients.

Further details of ACE will be found in UK patent specification GB-A-2 059 712 and in 'Four-field digital standards converter for the eighties' by R N Robinson and G J Cooper at Pages 11 to 13 of "Television" (the journal of the Royal Television Society) for January/February 1982.

Although ACE gives good results, there is the problem that the equipment is very bulky. To overcome this problem, we have previously proposed a television standards converter comprising three field stores and four 4-line stores for receiving an input digital television signal of one standard and deriving therefrom arrays of sixteen lines, each array consisting of four successive lines from each of four successive fields of the input television signal. A weighting coefficient store stores sets of sixteen weighting coefficients, respective sets corresponding to positions both spatial and temporal of respective lines of an output digital television signal of a different standard, relative to the sixteen lines of the input television signal. Two interpolation filters then derive line by-line the output television signal by multiplying corresponding sample values from each of the sixteen lines of the input television signal by a respective weighting coefficient in a set of weighting coefficients and sum the resulting products to form an interpolated sample value, and four output field stores receive and store the derived lines of the output television signal. To store the additional lines which are derived when the output television signal has more lines than the input television signal, a 45-line store is interposed between one of the interpolation filters and the output field stores. Further details will be found in our UK patent specification GB-A-2 140 644.

The performance of such standards converters which employ vertical/temporal interpolation techniques represents a compromise between generating blurred pictures while maintaining good motion portrayal and maintaining vertical resolution but at the expense of 'judder'. The former is a result of post filtering in order to prevent disturbing alias effects; the latter is a result of the intrusion of the adjacent two-dimensional repeat sample structures.

We have therefore proposed that motion vector estimation should be incorporated in television standards converters and in slow motion processors. The problem with the majority of existing motion vector estimation methods is that their use is biased towards video conference type applications where generally the subject matter is either a single person's head and shoulders or a small group of people seated around a table. With television images of this type the motion is relatively simple in comparison with broadcast television images where for example at a horse race meeting the camera could be following the leaders in a race. In this situation the motion would be complex, for example, because the camera would be panning. Thus, the background may well be moving at speeds greater than eight pixels per field, while in the foreground there would be at least one horse galloping. This means that the motion vector estimation method must try to track the horses legs, which may well be moving in different directions to that of the already moving background.

There are therefore problems in estimating appropriate motion vectors and in particular in arriving at a final single motion vector corresponding to each pixel of the television image, such that the motion of that pixel can be represented smoothly even in the presence of discontinuities such as scene changes, and some noise.

According to the present invention there is provided a television standards converter comprising:

means for analyzing the motion between consecutive fields of an input television signal of one television standard and for deriving motion vectors in dependence on said motion;

characterized by:

means recursively to filter said motion vectors;

means then to align said fields in dependence on said filtered motion vectors so as effectively to

represent static pictures; and
means to effect conversion using said static pictures to derive the required output television signal of a different television standard.

According to the present invention there is also provided a 625-line 50-fields per second to 525-line 60-fields per second television standards converter comprising:
a first time base corrector for receiving an input 625-line 50-fields per second digital television signal;
characterized by:
a motion analyzer connected to the output of said time base corrector for analyzing motion in said input television signal and for deriving motion vectors in dependence on said motion;
means recursively to filter said motion vectors;
a shift register also connected to the output of said first time base corrector;
an interpolator for deriving samples of a required output 525-line 60-fields per second digital television signal in dependence on samples derived from said shift register and said filtered motion vectors; and a second time base corrector for assembling said derived samples to form said output television signal.

According to the present invention there is also provided a 525-line 60-fields per second to 625-line 50-fields per second television standards converter comprising:
a first time base converter for receiving an input 525-line 60-fields per second digital television signal;
characterized by:
a motion analyzer connected to the output of said time base corrector for analyzing motion in said input television signal and for deriving motion vectors in dependence on said motion vectors;
means recursively to filter said motion vectors;
a shift register also connected to the output of said first time base corrector;
an interpolator for deriving samples of a required output 625-line 50 fields per second digital television signal in dependence on samples derived from said shift register and said filtered motion vectors; and a second time base corrector for assembling said derived samples to form said output television signal.

According to the present invention there is also provided a slow motion processor comprising:
an input circuit for receiving an input digital television signal;
a motion analyzer for analyzing motion in said input digital television signal and for deriving motion vectors in dependence on said motion;
characterized by:
means recursively to filter said motion vectors;
a shift register for holding successive different fields of said input television signal;
an interpolator for deriving samples of a required slow motion output digital television signal in dependence on the degree of slow motion, samples derived from said shift register, and said filtered motion vectors; and
a 2-field time base corrector for assembling said derived samples to form said slow motion output television signal.

The invention will now be described by way of example with reference to the accompanying drawings, throughout which like parts are referred to by like references, and in which;

Figure 1 shows in very simplified block diagrammatic form a television standards converter;

Figure 2 shows in block diagrammatic form a first television standards converter;

Figure 3 shows in block diagrammatic form a second television standards converter;

Figure 4 shows part of the standards converter of Figure 3 in more detailed block diagrammatic form;

Figure 5 shows time charts for explaining the operation of Figure 4;

Figure 6 shows part of the standards converter of Figure 2 in more detailed block diagrammatic form;

Figure 7 shows time charts for explaining the operation of Figure 6;

Figure 8 shows part of the standards converter of Figure 2 in more detailed block diagrammatic form;

Figure 9 shows time charts for explaining the operation of Figure 8;

Figure 10 shows part of the standards converter of Figure 2 in more detailed block diagrammatic form;

Figure 11A shows diagrammatically the motion of an object in sequential fields;

Figure 11B shows corresponding motion vectors;

Figure 12 shows in block form the comparison of motion vectors;

Figures 13 to 15 show respective examples of motion vectors from three sequential fields;

Figure 16 shows the effect of recursive filtering of motion vectors;

Figure 17 shows in block form a general example of an infinite impulse response filter;

Figure 18 shows diagrammatically negative vector filtering;

Figure 19 shows in block form an infinite impulse response filter for negative vector filtering;

Figure 20 shows diagrammatically positive vector filtering; and

Figure 21 shows in block form an infinite impulse response filter for positive vector filtering.

In order more readily to understand the motion

vector processing to be described, the form and operation of two standards converters and a slow motion processor in accordance with the present invention which use such motion vector processing will first be described. The standards converters to be described maintain vertical resolution and remove the 'judder' by compensating for motion between fields. In effect the motion between consecutive fields is analyzed. These fields can then be 'aligned' pixel by pixel such that they represent static pictures upon which conversion can then take place. As a result, vertical resolution can be maintained.

The standards converters to be described can be divided into two parts. The first part is analogous to a known standards converter performing vertical/temporal interpolation to convert between 525/60 and 625/50 television standards. Alone, this would generate an output in which vertical resolution would be maintained but with the added effect of judder. To remove this judder four fields of the input digital television signal which are used in the conversion process are aligned under the control of motion vectors generated from a motion analyzer which forms the second part of the standards converter.

This is shown in very simplified diagrammatic block form in Figure 1. The video portion of an input digital television signal of one standard, which may for example have been derived by sampling an analogue television signal at 13.5 MHz, is supplied to an interpolator 1 from which the video portion of the required output television signal of a different standard is derived. A motion analyzer 2 receives the luminance video and derives motion vectors which provide data representing the motion between successive fields of the input television signal to control the operation of the interpolator 1. The interpolator 1 operates in a generally similar manner to the corresponding portion of a known standards converter, for example as referred to above. It also, however, contains the means to align the four fields used in the interpolation, under the control of the motion vectors.

The repositioning of the four fields is performed in two stages. The first stage involves varying the address of a variable delay element associated with each field to reposition the picture to the nearest line or sample. The second stage uses interpolation techniques both vertically and horizontally to reposition to within ±1/16 line or ±1/8 of a sample. Even with no movement, both the above techniques are used to enable conversion of line standards.

The vertical interpolator has four taps per field allowing effectively an 8-tap vertical filter to be applied to the static pictures. An 8-tap interpolator allows good vertical resolution to be maintained with minimal distortion. The effect of distortion in the horizontal interpolator is less of a problem, so a 2-tap horizontal filter is used, although a 4-tap horizontal filter, for example, may be used.

The temporal interpolator is used in normal operation to enable interpolation of perspective changes or when no sensible motion vector can be detected, in which case the interpolator 1 must revert to normal standards conversion operation where no picture re-positioning occurs.

When converting from a high field rate to a lower rate, the incoming fields are interpolated such that an interpolated field can occasionally be dropped without any movement deterioration. All the interpolation is done at the input field rate and passed to a time base corrector which then spreads the fields generated over the required time period for the output standard.

The above operation is necessary when converting from 525/60 to 625/50. It is also evident however that 625 lines must be generated where only 525 lines exist in the input signal.

To overcome the line number conversion problem a second time base corrector is used at the input to produce a signal having 585 lines at the 60 Hz rate. A 585-line format can contain all the active picture information in the 625-line format. Following this first time base corrector there are occasional lines which have no video information. The interpolator stores are frozen during this time, so that an additional interpolated line can be generated from the same lines used to generate the previous output line. This process allows 625 lines to be interpolated from the original 525.

The reason for selecting the 585/60 format will now be explained in more detail. A 625-line picture contains 288 active lines in each field, and 720 samples in each horizontal line at the sampling rate of 13.5 MHz. The circuits, to be described below, of the television standards converters of Figure 2 and 3 use techniques which allow the picture to be shifted horizontally by plus or minus twenty-four samples. This requires a minimum horizontal blanking of forty-eight samples. The total number of sample positions required in a field is therefore:

(720 + 48) x 288 = 221184.

There are clearly considerable advantages in using a 13.5 MHz clock throughout the system, in which case the number of clock cycles within a 60 Hz period (more exactly a 59.94 Hz period) is:

225225.

If 576 lines of data are required in one frame, the number of horizontal samples would be 782.03125. Although this number is sufficient to contain the required (720 + 48) samples, the fractional sample would mean that the structure was non-orthogonal on a line to line basis. This would cause significant design difficulties in the rest of

the standards converter, so the number of lines required was gradually increased, from 576, until a whole number of samples, in fact 770, existed in each line.

The only format that achieves the orthogonal structure is the 585/60 format, which in addition gives a useful vertical blanking of four lines in the first field, five lines in the second field and fifty samples of horizontal blanking.

In the 625/50 to 625/50 slow motion mode referred to below there is no requirement to store the active video of the 625 format within a 60 Hz period, so the interpolation and other processing is done in the normal 625/50 format.

When converting from a low field rate to a higher rate the input time base corrector is required to produce a video stream at the output rate. This is done by occasionally repeating an input field. When the repeated field occurs, all the interpolator stores must be frozen so that the interpolation is applied to the same input fields used to create the previous output field.

If this technique were not used, two sets of interpolator and movement detector would be required to make up the missing field.

The above operation is performed when converting from 625/50 to 525/60. To allow 625 lines to exist during a 60-fields per second period again requires the 585/60 intermediate format to be adopted. During this process some of the interpolated lines will not be required, as only 525 have to be produced from the original 625. A time base converter is therefore required on the output to produce the final 525/60 format.

The amount of interpolation required is determined by comparing input and output synchronization pulse phases.

As mentioned above, motion analysis is performed on the luminance of the input video. The method employed involves a number of stages to arrive at a single motion vector for each pixel. Movement can be detected in the range ±24 pixels horizontally and ±8 (field rate) vertically.

In a first stage, motion in the picture at points on the screen spaced sixteen samples horizontally and eight lines vertically is determined using a block matching technique. The original motion vectors in a field are calculated every sixteenth sample and every eighth line. Each one of these points is at the centre of a search block. Conceptually each block is scanned ±24 samples horizontally, and +8 and -8 samples vertically over the next field each time generating the summation of the differences between the two fields over the area of the search block. The minimum overall difference then indicates in which direction the object at that point has moved.

In practice, the above technique is applied in separate steps which greatly reduces the amount and complexity of hardware required:

Step 1.

Test for minimum difference in just three positions, centre position, sixteen samples to the left, sixteen samples to the right.

Step 2. Starting from point indicated above.

Test for minimum difference in nine positions symmetrically distributed about the above starting point in steps of eight samples or lines.

Step 3. Starting from point indicated above.

Test for minimum difference in nine positions symmetrically distributed about the above starting point in steps of four samples or lines.

Step 4. Starting from point indicated above.

Test for minimum difference in nine positions symmetrically distributed about the above starting point in steps of two samples or lines.

Step 5. Starting from point indicated above

Test for minimum difference in nine positions symmetrically distributed about the above starting point in steps of one sample or line.

Step 6.

After step 5, the motion of the object has been detected to the nearest pixel. A more accurate vector value can be achieved by adding a sixth step in which the difference produced at the final position indicated by step 5 is compared with the two differences above and below to adjust the vertical vector value and with the two differences to the left and right to adjust the horizontal vector value.

The above technique relies on achieving correlation between the reference search block and a similar block of video data on the following field (the search positions). In step 5 it is possible the true movement was a half pixel more or less than detected, but it is necessary for the best correlation to occur at this point, even although exact correla-

tion cannot be achieved. To ensure this occurs, the picture can be filtered both vertically and horizontally by a gaussian filter which has +6 dB attenuation at 1/2 Nyquist frequency.

Similarly, for step 4, the picture can be filtered with a 6 dB attenuation at 1/4 Nyquist frequency, which allows a one pixel error in detection.

Step 3 uses a picture filtered with a 6 dB attenuation at 1/8 Nyquist frequency allowing a two pixel error.

Step 2 uses a picture filtered with a 6 dB attenuation at 1/16 Nyquist frequency allowing a four pixel error.

Finally, step 1 uses a picture filtered with 6 dB attenuation at 1/32 Nyquist frequency allowing an eight pixel error. In addition, because the pictures are so heavily filtered during steps 1, 2, 3 and 4, the samples can be reduced, for example halved in number, which still further greatly reduces the number of calculations and amount of hardware required.

The effective search block size is sixteen lines high and forty-eight samples long. A large search block is necessary to detect accurately the movement of large plain areas. The central part of plain areas are unimportant as the values of the pixels at these points do not change from one field to the next, but the edges of such objects are obviously important. If the detection of motion is limited to ±24 samples horizontally and ±8 lines vertically then a block of the above size would be the minimum size to ensure accurate motion detection.

In the standards converters, depending upon the conversion modes, the luminance video entering the motion analyzer 2 is in various forms of 585-lines/60-fields per second. This might comprise repeated lines for 525 input or repeated fields for 625 input. In addition, the input contains both field polarities. The first process is to ensure a continuity of data and single field polarity for the motion estimation processing. This is done by interpolation on the input data by a vector interface to maintain continuity, and filtration horizontally to aid subsequent motion detection/correlation.

Separate outputs from this circuit are passed to motion estimation vector filters and motion detection field stores/vector selectors. The output of the vector interface is, as described above, spatially continuous, single field polarity data. The output to the field stores/vector selectors depends upon the input and output modes. In some modes it is continuous, and in others it contains repeated lines/fields. The vector filters and vector calculators perform the steps outlined above.

The processing of the various steps is performed by vector calculators and a vector processor. The vector calculators perform steps 1 to 5 and the vector processor performs step 6. In addition, the vector processor performs the second stage in the motion estimation, as follows:

For each 8 x 16 block a choice is made of four from seven motion vectors, the seven motion vectors being the one for that particular block and the six for the six nearest blocks respectively.

In addition, the vector processor also determines the four most common motion vectors throughout the whole input field, these being called modal motion vectors. The primary use of the modal motion vectors is in the border areas close to the edge of a field where it is not possible actually to calculate any local motion vectors. Also, if any one or more of the local motion vectors are equal, then these are substituted for by the modal motion vectors.

In the next stage of motion detection, for each pixel, the four motion vectors are tested by producing the difference between the extrapolated positions on field 0 to field 1. During standards conversion a field needs to be interpolated between two fields; say between field 0 and field 1. So the motion vectors generated between these two fields are considered to be most representative of the motion. Four motion vectors are used from these two fields. To decide which is the correct motion vector a pixel from field 0 is compared with a pixel from field 1 using the motion vector to decide where the pixel to be generated had come from on field 0 and where it has gone to by field 1. Mathematically, if the position x, y, z must be generated, where; x = horizontal position, y = vertical position, z = temporal position between field 0 and field 1, the pixels used for comparison are as shown below. Field 0 is assumed to be at z=0 and field 1 at z=1.

Pixel from field 0

$x^0 = x - (V_h{}^*z)$

$y^0 = y - (V_v{}^*z)$

Pixel from field 1

$x^1 = x + (1-z)V_h$

$y^1 = y + (1-z)V_v$

V_h = horizontal component of vector

V_v = vertical component of vector

For each motion vector a modulus of the difference between the pixels indicated in field 0 and field 1 is found. The minimum difference is assumed, as a first estimate, to indicate the correct motion vector. If a number of motion vectors produce a very similar difference then these motion vectors are tested again using a comparison between fields -1 and 0.

Pixels from field -1

$x^{-1} = x - (1+z)V_h$

$y^{-1} = y - (1+z)V_v$

The minimum modulus of difference of the remaining motion vectors produced by this second test is then considered to represent most accurately the

motion vector.

If a number of motion vectors again have similar differences then an option exists to assume no movement. If only the horizontal component varied and the vertical component did not, then only the horizontal component would be set to zero and the vertical component would be maintained at the detected value. If only the vertical component varied, then the horizontal component would be maintained and only the vertical component set to zero. If the pixel difference chosen is too large then an option exists to set the whole motion vector to zero in both directions.

A final stage is applied once every pixel has been assigned a motion vector. Here the motion of each pixel is tracked from one field to the next and a recursive filter applied to the vector value. This removes the effects of noise and small movement estimation errors and also smooths the trajectory of the motion vectors.

There are two possible ways of tracking the motion of a pixel.

In the first, the motion vector for a pixel in field t is used to point to a pixel in field (t+1). The motion vector determined for this pixel in field (t+1) is then recursively filtered to form the final motion vector for the pixel in field (t+1).

In the second, the motion vector for a given pixel in field t is used to point to a pixel in field (t-1). The motion vector from this pixel is then recursively filtered with the motion vector for the given pixel to form the final motion vector for this given pixel in field t.

In either case the final output is a motion vector for each pixel which is passed from the motion analyzer 2 to the interpolator 1 to be employed in aligning the four fields used in the standards conversion process.

The first standards converter for converting an input digital 625-line 50-fields per second television signal to an output digital 525-line 60-fields per second television signal is shown in detailed block form in Figure 2.

The incoming video at 50-fields per second and a sample rate of 13.5 MHz, that is CCIR 601 data, is supplied to a demultiplexer 31 which separates it into luminance components Y, synchronizing signals SYNC and chrominance components UV. The luminance components Y are supplied to a 4-field luminance time-base corrector (TBC) 11Y and the chrominance components UV are supplied to a 4-field chrominance TBC 11C. The synchronizing signals SYNC are supplied to a control 32 together with an input field polarity signal from an external input, and an output field synchronizing reference signal from another external input. The TBCs 11Y and 11C occasionally repeat fields, so that the output is at 60-fields per second. The control to the TBCs 1Y and 11C which causes the repetition of a field is derived from the input field synchronization pulses, and the required output field synchronization pulses. The comparison of the synchronization pulses also provides a temporal offset figure which indicates the amount of temporal interpolation required at the outputs of the TBCs 11Y and 11C such that smooth motion at 60-fields per second would be observed.

When converting from 50-fields per second to 60-fields in this way a line conversion of 625 to 525 is necessary. It is therefore necessary to maintain the original 625 lines of information at a 60-fields per second rate so that they are all available to form the interpolated lines.

The standards converter uses an intermediate standard which is capable of containing all the active vertical information of the 50-fields per second signal at the 60-fields per second rate. The intermediate standard also contains all the active line information arranged orthogonally line by line still using the original 13.5 MHz sample rate.

The intermediate standard use, and which is as explained above capable of meeting all these requirements, is a 585-line format at 60-fields per second. When sampled at 13.5 MHz each line of this format has exactly 770 samples. It is clear therefore that 585 lines is sufficient to contain the 576 active lines of the 625-line format at a 60-fields per second rate. As the active line width is only 720 samples there is still fifty samples of horizontal blanking.

The luminance data (D) from the luminance TBC 11Y is supplied by way of a processing compensating delay 17Y to a luminance temporal shift register 16Y comprising four field stores (FS) 12Y, 13Y, 14Y and 15Y. The luminance TBC 11Y also supplies a temporal freeze signal (F) by way of the delay 17Y to the shift register 16Y. The chrominance TBC 11C supplies the chrominance data (D) by way of a processing compensating delay 17C to a chrominance temporal shift register 16C which comprises four field stores 12C, 13C, 14C and 15C. The chrominance TBC 11C also supplies a temporal freeze signal by way of the delay 17C to the shift register 16C. Associated with the shift register 16Y is a luminance interpolator 1Y which receives inputs from each of the field stores 12Y, 13Y, 14Y and 15Y, and derives the 585-line format. The output of the luminance interpolator 1Y is supplied to a 2-field luminance TBC 18Y. Associated with the shift register 16C is a chrominance interpolator 1C which receives inputs from each of the field stores 12C, 13C, 14C and 15C, and also derives the 585-line format. The output of the chrominance interpolator 1C is supplied to a 2-field chrominance TBC 18C. When the outputs of the TBCs 11Y and 11C are frozen, during a repeat

field, the shift registers 16Y and 16C are also frozen, so that four distinct consecutive fields of the input always exist in the shift registers 16Y and 16C. Thus the shift registers 16Y and 16C are used to provide the temporal taps for the interpolators 1Y and 1C. The present invention is particularly concerned with the interpolators 1Y and 1C.

Each temporal tap produces four line taps at a position depending on the motion vectors, so that a two-dimensional filter can be used to provide the necessary interpolation. The interpolated picture will contain 576 active lines, so that a correct picture will be obtained when every sixth line in one field is dropped. The 484 lines left produce the active picture portion of the 525-line format. To enable lines to be dropped in this way, the outputs from the interpolators 1Y and 1C are supplied to the 2-field TBC 18. The TBCs 18Y and 18C write in all 576/2 lines, but only read out the required 484/2 lines to provide the required output television signal. The outputs of the luminance TBC 18Y and of the chrominance TBC 18C are supplied to a multiplexer 34 which multiplexes the luminance components Y and the chrominance components UV to provide output CCIR 601 data in the form of a digital 525-line 60-fields per second television signal.

The control 32 supplies control signals (C) to the luminance TBC 11Y and to the chrominance TBC 11C. The control 32 also supplies control signals to the luminance TBC 18Y and the chrominance TBC 18C. It also supplies interpolation control signals (IC) to the luminance interpolator 1L and the chrominance interpolator 1C.

The luminance data only, as supplied by the luminance TBC 11Y, is also supplied to the motion analyzer 2 shown in the upper part of Figure 2, so that motion vectors can be generated. In fact a frame delay is necessary between the TBCs 11Y and 11C and the shift registers 16Y and 16C to allow for the time taken to process the motion vectors. The freezing of the shift registers 16Y and 16C must therefore also be delayed by one frame, and these delays are provided by the delays 17Y and 17C.

The motion analyzer 2 comprises a vector interface 35 to which the luminance data from the luminance TBC 11Y is supplied, together with the interpolation control signal from the control 32. The vector interface 35 supplies data interpolated to 625 lines to a vector filter 36 and a vector calculator 37 which together perform the motion estimation described above. The output of the vector calculator 37 is supplied to a modal motion vector processor 38 and also to a sub-pixel motion estimator. The motion vector processor 38 supplies four outputs and the sub-pixel motion estimator one output to a motion vector reducer 40 which supplies four outputs to a vector selector 41, with which the present invention is particularly concerned.

The vector interface 35 also supplies the data interpolated to even fields to a processing compensating delay 42 to which it also supplies the received interpolation control signal, and also a temporal freeze signal (F) generated at the vector interface 35. The data from the delay 42 is supplied to a temporal shift register 43 which comprises three field stores 44, 45 and 46 which supply respective data outputs to the vector selector 41. The delay 42 supplies the interpolation control signal to the vector selector 41 which supplies the selected motion vector to a recursive motion vector filter 47, the output of which is the motion vector data which is supplied to the luminance interpolator 1Y and to the chrominance interpolator 1C.

The way in which the motion analyzer 2 derives the motion vector data has been described in detail above, and will be further described below, but the operation of the elements 35 to 43 and 47 will now be briefly described.

The vector interface 35 receives the luminance data from the luminance TBC 11Y, and the interpolation control signals from the control 32. It supplies 625-line data, normally contained within the 585/60 format, to the vector filter 36. It also supplies data to the delay 42. These data must contain a picture which is the same line standard as the required output, again normally contained within the 585/60 format. Each field of the interpolated data is also made to appear even.

The vector filter 36 produces the filtered picture data required for steps 1 to 5 above of the motion detection. The filtered picture data are supplied in sample reduced form to the vector calculator 37.

The vector calculator 37 operates on the filtered and sample-reduced data from the vector filter 36 using an algorithm described in the terms of the steps 1 to 5 above of the motion detection. The process is essentially a two-dimensional binary search for motion down to pixel/line resolution. For each field, 1200 motion vectors are generated and are supplied to both the modal motion vector processor 38 and to the sub-pixel motion estimator 39. It also supplies surrounding weighted absolute difference (WAD) values as calculated by step 5 above to the sub-pixel motion estimator 39. For details of WAD calculations, see 'Advances in Picture Coding', Musmann et al, Proceedings of the IEEE, April 1985. The specific WAD value which is the minimum in step 5 above of the motion detection provided a figure of merit (FOM).

The vector processor 38 calculates the four most common motion vectors that are detected in each field and supplies them to the vector reducer

40.

The sub-pixel motion estimator 39 receives the motion vectors from the vector calculator 37 together with the surrounding WAD values. From these it estimates sub-pixel movement to be appended to the motion vector values. With each motion vector its corresponding final WAD value is also supplied to the vector reducer 40.

The vector reducer 40 receives the motion vectors from the vector processor 38 and from the sub-pixel motion estimator 39. For each motion vector from the sub-pixel motion estimator 39, the six motion vectors closest to it are grouped together. For each motion vector there are then eleven choices. The reduction process selects four motion vectors from the eleven for supply to the vector selector 41.

The vector reducer 40 supplies the vector selector 41 with four representative motion vectors for each sixteen pixel by eight line block of the picture. By comparing pixels over three fields, the vector selector 41 selects the single best motion vector for each pixel in the picture, as described in more detail below. The motion vector selected is supplied to the motion vector filter 47.

The delay 42 delays the data by one frame less twenty-one lines to compensate for other delays in the system.

The temporal shift register 43 holds and supplies the three fields of data used by the vector selector 41.

The motion vector filter 47 tracks a motion vector from one field to another so applying some filtering to the motion vectors by combining motion vectors in different fields, so reducing motion detection errors. The output of the motion vector filter 47 is supplied to the luminance and chrominance interpolators 1Y and 1C to control the alignment of the field data.

Exactly the same hardware can be used as a slow motion processor with good motion portrayal for either a 625/50 or a 525/60 television signal. It is not however necessary to use the vertical interpolator to provide the line number conversion. In all cases the control 32 determines what action is required by recognizing the input/output standard from the input and output field synchronization pulses. In slow motion the input field polarity is used.

Whereas in 50-fields per second to 60-fields per second conversion a field was occasionally repeated, in slow motion the field is repeated the same number of times as the input field is repeated. As repeated fields are not written into the shift registers 16Y and 16C, the shift registers 16Y and 16C again contain distinct consecutive fields. Indeed if a video tape recorder reproduces without any interpolation of its own, the original interlace structure is maintained allowing full resolution pictures to be produced. The temporal offset required is calculated by comparing the actual field rate pulses, by they 50-fields per second or 60-fields per second, with the rate at which a new field is received. To determine the temporal offset in this way, the system needs a signal to be available which indicates the true field polarity of the field being repeatedly replayed. The vertical interpolator will always produce the field polarity required at the output.

Conceptually the TBCs 11Y and 11C are not really required for slow motion operation, but their presence does provide a frame synchronization facility and also simplifies the system configuration.

The second standards converter for converting an input digital 525-line 60-fields per second television signal to an output digital 625-line 50-fields per second television signal is shown in detailed block form in Figure 3.

In this case, interpolation requires that all the input data is available in a consecutive form. In this case it would not therefore be possible to convert to 50-fields per second before the interpolators 1Y and 1C. The input data however contains only 484 active lines and the interpolators 1Y and 1C must produce 576. The 2 field TBCs 18Y and 18C are therefore positioned at the front of the standards converter to provide the necessary time slots for 484-line to 576-line conversion.

The original continuous line structure is written into the TBCs 18Y and 18C but is read out in the 585-line standard with approximately every sixth line being blank. The interpolators 1Y and 1C are then used to produce a continuous picture at the output line rate by freezing its line stores during the blank input line, and producing the required additional line at the output, so ensuring that a spatially correct picture is produced. The required temporal offset is detected and applied as in the first standards converter, although the interpolation is applied such that a field can occasionally be dropped leaving the motion smooth. The field is dropped such that 60-fields per second to 50-fields per second conversion is achieved. The dropping of a field is achieved by using the 4-field TBCs 11Y and 11C at the output.

Thus the second standards converter differs from the first standards converter shown in Figure 2 in only minor respects. In particular, the luminance TBCs 11Y and 18Y are interchanged, and the chrominance TBCs 11C and 18C are also interchanged. Also, no temporal freeze signals are required.

In both cases the control 32 has various functions as follows; controlling the reading and writing of the TBCs 11Y, 11C, 18Y and 18C; generating a temporal offset number, and in the case of the first

standards converter the temporal freeze signal, and generating a vertical offset number together with vertical interpolation control signals. These functions will now be described in more detail.

Firstly, the 2-field luminance and chrominance TBCs 18Y and 18C always switch between field stores at the end of every 60 Hz field. However, the operation of the 4-field luminance and chrominance TBCs 11Y and 11C depend on the mode of operation, and their control is also associated with the generation of the temporal offset signal. In fact, the control of the luminance and chrominance TBCs 11Y and 11C is determined from the input and output field synchronizing signals.

The derivative of the temporal offset signal in the case of 525/60 to 625/50 operation will now be described with reference to Figures 4 and 5.

In Figure 4, the control 32 is shown as including a line counter 61, and first and second latches 62 and 63. A line clock signal is supplied to a clock terminal of the line counter 61, while the input field synchronizing signal is supplied to a reset terminal of the line counter 61 and to a clock terminal of the second latch 62. The output field synchronization signal is supplied to a clock terminal of the first latch 62. The output of the line counter 61 is supplied to the input of the first latch 62, the output of which is supplied to the input of the second latch 63, the output of which is the temporal offset signal supplied to the luminance and chrominance shift registers 11Y, 11C, 18Y and 18C.

The input and output field synchronizing signals are shown in Figures 5A and 5B respectively. Figure 5C shows the output of the line counter 61 which repetitively counts from 0 to 524. Figures 5D and 5E show the outputs of the first and second latches 62 and 63 respectively. By latching the counter 61, the required proportion of the input field period is determined. The temporal shift value tn indicates the position between two input fields where the output field must be interpolated such that when the shaded field shown in Figure 5A is dropped, continuous motion still occurs. Thus, the field which uses the temporal offset shown shaded in Figure 5E is the one that is dropped. It will be seen by reference to Figures 5A and 5B, that the field which is dropped is the one which does not have a new temporal shift associated with it. The field (arrowed) which is to be dropped is indicated to the following circuitry by the temporal freeze signal.

The derivation of the temporal offset signal in the case of 625/50 to 525/60 operation will now be described with reference to Figures 6 and 7.

In Figure 6, the control 32 is shown as including a line counter 71 and a latch 72. A line clock signal is supplied to a clock terminal of the line counter 71, while the input field synchronizing signal is supplied to a reset terminal of the line counter 71. The output field synchronization signal is supplied to a clock terminal of the latch 72. The output of the line counter 71 is supplied to the input of the latch 72, the output of which is the temporal offset signal supplied to the luminance and chrominance shift registers 11Y, 11C, 18Y and 18C.

The input and output field synchronizing signals are shown in Figures 7A and 7B respectively. Figure 7C shows the output of the line counter 71 which repetitively counts from 0 to 624. Figure 7D shows the output of the latch 72. By latching the counter 71, the required proportion of the input field period is determined. Thus, the temporal shift value tn again indicates the position between two input fields where the output field must be interpolated, such that if the shaded field is repeated, continuous motion still occurs. The field which is repeated is the one which has two temporal shift values associated with it. The field (arrowed) which is to be repeated is indicated to the following circuitry by the temporal freeze signal.

The deviation of the temporal offset signal in the case of slow motion whether at 525/60 to 525/60 or 625/50 to 625/50 is the same, and will now be described with reference to Figures 8 and 9.

In figure 8, the control 32 is shown as including a line counter 81, a field counter 82, first to fourth latches 83 to 86, an exclusive-OR gate 87 and a scaler 88. The input field synchronizing signal is supplied to a clock terminal of the first latch 83, to a clock enable terminal of the field counter 82, and to a second reset terminal of the line counter 81. The input field polarity signal is supplied to the first latch 83 and thence to the second latch 84 and also to one input of the gate 87. The second latch 84 supplies an output to the second input of the gate 87, the output of which is supplied to a first reset terminal of the line counter 81, to a reset terminal of the field counter 82 and to a clock terminal of the third latch 85, which forms a speed detector latch. A line clock signal is supplied to a clock terminal of the second latch 84, and to respective clock terminals of the line counter 81 and the field counter 84. The output of the line counter 81 is supplied to an input terminal of the scaler 88, and the output of the field counter 82 is supplied to an input of the third latch 85 and also to an offset input terminal of the scaler 88. The output field synchronizing signal is supplied to a clock terminal of the fourth latch 86. The output of the third latch 85 is supplied to a scale factor terminal of the scaler 88, the output of which is supplied to the fourth latch 86, the output of which is the temporal offset signal.

The input field synchronizing signal and the

input field polarity signal are shown in figures 9A and 9B respectively. Figure 9C also indicates the input field synchronizing signals and Figure 9D the output field synchronizing signals. Figures 9E and 9F indicate the operations of the field counter 82 and the line counter 81, which are respectively counting fields and lines from 0 to N. Figure 9G indicates the output of the fourth latch 86 which is the temporal offset signal. Figure 9H indicates the temporal freeze signal (which is active when low), and, as indicated by the arrows, the shaded field that uses the temporal offset shown in a repeat of the previous field that used the temporal offset t1.

To generate the temporal freeze signal, the control 32 is shown in Figure 10 as including a synchronous RS flip-flop 91, a latch 92, an inverter 93 and an AND-gate 94. The output field synchronizing signal is supplied to one input of the flip-flop 91, to the input of the inverter 93 and to a clock enable terminal of the latch 92. The input field synchronizing signal is supplied to the other input of the flip-flop 91, while a line clock signal is supplied to clock terminals of the flip-flop 91 and the latch 92. The output of the flip-flop 91 is supplied to one input of the gate 94, which receives at its other input the output of the inverter 93. The output of the gate 94 is supplied to the input of the latch 92, the output of which forms the temporal freeze signal. The operation of this circuit is such that if more than one output field synchronizing pulse follows an input field synchronizing pulse, a freeze occurs.

Referring back to Figure 2, the generation of the vertical offset number by the control 32 will now be described. The same address generator which reads data from the luminance TBC 11Y into the luminance interpolator 1Y and the motion analyzer 2, also addresses an erasable programmable read-only memory (EPROM) which provides the vertical offset number together with vertical freeze signals when required.

(In the Figure 3 arrangement which is used for 525/60 to 625/50, the read addresses of the luminance TBC 18Y are used, but in all other modes the read addresses of the luminance TBC 11Y are used.)

The vertical offset number is generated assuming that both the input and the output fields are even, and it then indicates the position between two input lines where the output line must be interpolated such that a non-distorted picture would be produced if: a line were occasionally dropped in 625/50 to 525/60 conversion, or
a line were occasionally repeated in 525/60 to 625/50 conversion.

When a line is repeated by the luminance TBC 11Y (18Y), a vertical freeze signal is generated.

If the input fields are not both even, then the interpolators 1Y and 1C must make use of the input field polarity and output field polarity to ensure correct interpolation.

The contents of the EPROM are generated in a way similar to that described above in connection with Figure 10 for the temporal offset signal, using the known line position in both a 525 and a 625 picture.

The form and operation of the motion vector filter 47 (Figure 2), with which the present invention is particularly concerned, will now be described in more detail with reference to Figures 11 to 21.

As stated above, the vector reducer 40 supplies the vector selector 41 with four representative vectors for each sixteen pixel by eight line block of the picture. By comparing pixels over three fields, the vector selector 41 selects the single best motion vector for each pixel in the picture, and this motion vector is supplied to the motion vector filter 47 where motion of each pixel is tracked from one field to the next and recursive filtering applied to the motion vector value. This removes the effects of noise and small movement estimation errors and also smooths the trajectory of the motion vectors.

There are two possible ways of tracking the motion of a pixel.

In the first (negative vector) mode, the motion vector for a given pixel in field t is used to point to a pixel in field (t-1). The motion vector from this pixel is then recursively filtered with the motion vector for the given pixel to form the final motion vector for this given pixel in field t.

In the second (positive vector) mode, the motion vector for a pixel in field t is used to point to a pixel in field (t+1). The motion vector determined for this pixel in field (t+1) is then recursively filtered with the motion vector for the given pixel to form the final motion vector for this given pixel in field (t+1).

This recursive filtering and associated processing will now be considered in more detail with reference to Figures 11 to 21. Basically the intention is that the filtered motion vectors used in the interpolation should be smooth and predictable in nature, so improving the overall subjective effect in the final picture. In this context the term 'recursive filtering and associated processing' actually encompasses two separate processes. The first is the actual 'recursive filtering' and the second could be termed 'majority vector determination', which is primarily concerned with the detection of motion vectors which are substantially different, for example as a result of a scene change. It should be noted that first and second does not necessarily indicate the order in which these processes take place and that the second process can be omitted in some embodiments.

Consider the motion of a single object across a

static background. When photographed and the resulting video passed to the standards converter, motion vectors are generated showing the trajectory of the object. Due to the video noise and small errors in determining the motion vectors it is unlikely that the motion vectors will be perfectly continuous. However, the motion of the object should be readily discernible as indicated in Figures 11A and 11B where Figure 11A indicates the motion of an object in sequential fields, and Figure 11B indicates successive motion vectors generated from sequential incoming fields.

By comparing the motion vectors from sequential fields, some erroneous conditions and some picture content information can be determined. For example, suppose the motion vectors from three sequential fields are derived as shown in Figure 12 by field stores 101 and 102, and are supplied to a comparator 103. The resulting comparisons are:

(a) In a first case (Figure 13):

(V_{t-2} is similar to V_{t-1}) are different from V_t

Vt is so significantly different from V_{t-2} and V_{t-1} that it seems likely that the motion of the object stopped at a point A (for example, as the result of a scene change). V_t should not therefore be considered as a continuation of V_{t-1} and V_{t-2}.

(b) In a second case (Figure 14):

(V_{t-2} is similar to V_t) are different from V_{t-1}

It appears likely that V_{t-2} and V_t are part of a continuous motion. Therefore, it is probable that there has been an error in calculating V_{t-1} and it should therefore be disregarded.

(c) In a third case (Figure 15):

V_{t-2} is similar to V_{t-1} is similar to V_t

The motion is continuous and it would be reasonable to assume that V_{t-2}, V_{t-1} and V_t represent the trajectory of the object.

It is apparent that in determining the equality, or inequality of the above vectors, some degree of flexibility must be included. It is unlikely that two sequential vectors will be identical but within defined limits of accuracy they might still represent continuous motion. The purpose of recursively filtering sequential motion vectors is to improve the motion portrayal of an object which might otherwise contain small errors. These small errors can arise as the result of noise in the incoming video affecting the generation of motion vectors and also as a result of small errors in the actual determination of these vectors. Figure 16 shows an example of the effect of recursive filtering in producing a resultant motion vector.

The recursive filtering is done in an infinite impulse response (IIR) filter generally as shown in Figure 17. The IIR filter comprises a multiplier 111 to which the input is supplied, an adder 112 from which the resultant motion vector is derived, and a field store 113 and a multiplier 114 forming a loop with the adder 112. Appropriate coefficients are supplied to the multipliers 111 and 114.

There are two possible implementations. They differ in respect of obtaining V_x from the field store 113. The first implementation is termed negative vector and the second is termed positive vector.

In the negative vector mode, consider the incoming motion vector V_t in Figure 18. The motion vector with which V_t is combined (V_x) must be obtained from the field store. In the negative vector mode this is done by using a negative version of V_t to point to the position in the previous field from which it came. Ideally, V_x should be the resultant motion vector to data of V_{t-1}, V_{t-2}, etc. However, it is unlikely that -(V_t) will point exactly to a resultant motion vector. Instead it will point to a resultant motion vector in the same vicinity as the required resultant motion vector. Generally the difference between the pointed to and required motion vector will be minimal and lead to a satisfactory output.

The modified IIR filter for the negative vector mode is shown in Figure 19. As compared with the basic filter of Figure 17, the input motion vector is additionally supplied to a negator 115, and the resulting negated input motion vector is supplied to an adder 116. A read address generator supplies basic read addresses for the field store 113 to the adder 116, while a write address generator 118 supplies write addresses directly to the field store 113.

The input motion vector for each pixel is represented by x,y coordinates, each of which is an 8-bit number. Therefore the bus width throughout the motion vector filter of Figure 19 is sixteen bits.

One motion vector enters the filter every clock cycle, and is passed to both a four clock cycle delay 119 and the negator 115. The purpose of the four clock cycle delay will be mentioned below. From the delay 119, the motion vector is passed to the 'input' multiplier 111 where it is multiplied by a coefficient 1. The coefficient 1 is continuously supplied to the multiplier 111 from a PROM 120. The value of the coefficient 1 is selectable under the control of an input 'coefficient select 1'. This, together with an input 'coefficient select 2', which is supplied to a PROM 121 that continuously supplies a coefficient 2 to the multiplier 114, allows the response to the filter to be actively changed, for example as the result of detecting the condition (a) in the majority vector determination.

The 16-bit output of the multiplier 111 is supplied to the adder 112 to be added to the output of the 'feedback' multiplier 114, that is the product of coefficient 2 and the output of the field store 113. The output of the adder 112 is the required smoothed output motion vector , and forms the output of the filter, as well as being supplied to the input of the field store 113.

The field store 113 comprises sufficient memory to store a field of motion vectors, which in the present case is 864 per line for each of 292.5 lines per field, a total of 252720 times sixteen bits. As motion vectors enter the field store 113 they are written into sequential locations addressed by the write address generator 118, which may simply be a counter chain clocked by the system clock, and reset at the beginning of each field by a field strobe pulse.

In this negative vector mode, the motion vector read from the field store 113 is obtained by using a negated version of the incoming motion vector to point to the approximate location of the resultant vector. This is done by first generating a sequential basic read address corresponding to the location in the field of the required motion vector if the value of the input motion vector were zero. To this is added the negated value of the actual input vector, so as to point to the location of the feedback vector. Using this address, the field store 113 is read and the feedback motion vector is supplied to the multiplier 114.

In the multiplier 114, the feedback motion vector is multiplied by coefficient 2, and the result of this multiplication is supplied to the adder 112.

The four clock cycle delay of the input motion vector is required to delay it from being passed to the multiplier 113 while the same motion vector is used to read a feedback motion vector from the field store 113. In other words, it takes four clock periods to negate the input motion vector, to add it to the basic read address, and to use the resulting read address to read the field store 113.

In the positive vector mode, consider the incoming motion vector V_t in Figure 20. This time, instead of affecting the read address of the field store 113, V_t affects the write address. Once the resultant motion vector from the combination of V_t and V_x has been determined, it is stored in the field store 113 at the location pointed to by the resultant motion vector.

The modified IIR filter for the positive vector mode is shown in Figure 21 where the same reference numerals are used for elements corresponding to those in Figure 19, even where the precise arrangement thereof is slightly different. In particular, it will be noted that the output of the adder 112 is supplied to the field store 113 by way of a delay 131 which is provided to compensate for the delay in a further adder 132, to which the output of the adder 112 is also supplied, and which also receives the basic write addresses from the write address generator 118. Finally, the output of the field store 113 is supplied to a concealment device 113 to which it also supplies concealment flags.

In the positive vector mode, as each input motion vector enters the filter, it is passed the 'input' multiplier 111 and multiplied by coefficient 1 as before. The result is then supplied to the adder 112 and added to the result of the feedback motion vector which has been multiplied by coefficient 2 in the 'feedback' multiplier 114. As before, the output of the adder 112 is the final smoothed motion vector which forms the output of the filter and is also supplied by way of the delay 131 to the field store 113 and directly to the adder 132.

Instead of being sequentially written in the field store 113, as in the negative vector mode, the motion vector is written into the location in the field to which it is pointing. That is, if the smooth motion vector is on line 30, for example, at sample position 50, and has a value +8, +2, then it will be written to location 30+8, 50-2.

This is done by first generating the basic write address, that is the address of the location where the motion vector would be written if the value of the motion vector were zero, for example 30, 50. The value of the motion vector, for example 8, 2, is then added to the basic write address to generate the actual write address 38, 48. This determination of the actual write address takes a few clock cycles, and therefore the motion vector is delayed accordingly at the data input to the field store 113 by the delay 131.

One field later the motion vector is read from the field store 113. This is done sequentially by the read addresses supplied by the read address generator 117, which again can be counter chain clocked by the system clock and reset by a field strobe pulse.

Subsequent to the field store 113 is the concealment device 133 which operates to conceal any locations which were not written in during the writing of the preceding field. The locations which require concealment are identified by a concealment flag which is passed, together with the motion vector, from the field store 113. The concealment flag is determined as follows.

During the reading of a field of motion vectors, the flag for each location is reset low as each location is read. Then, during the writing of the motion vectors, when a given location is written in, the respective flag is set high. Once a field of motion vectors has been written, any flags which remain low indicate a location which was not written in, and therefore requires concealing.

Two possible methods of concealment will now be briefly mentioned, either of which is selectable by a control signal indicated in Figure 21 as PosZero. The first method is simply to insert a motion vector with a value of zero. This will have the effect of causing the output of the filter to tend towards zero. However, the output will only actually begin to approach zero if a significant number of motion vectors on consecutive fields are concealed.

The second method is to replace with a spatially neighbouring motion vector. In the case where the concealed motion vector is one of a group of identical or substantially identical motion vectors, this will lead to better results. However, if it is not, the result of replacing with a wrong value can be worse than replacing with a value of zero. Because of this, and also if a series of motion vectors are to be replaced, that is, for example, a 'good' motion vector A is used to replace a 'bad' motion vector B, which is then used to replace a 'bad' motion vector C, account is kept of how many times a single 'good' motion vector is used to replace consecutive 'bad' motion vectors. Upon reaching a preset count, which may, for example, be in the range one to sixteen, concealment reverts to inserting zeros. After the concealment, the feedback motion vector is multiplied by coefficient 2 and supplied to the adder 112.

In practice, the field store 113 whether in the positive or negative vector mode may be divided into two parts. This is because it is necessary to have random access to the field store 113, this being required for reading in the negative vector mode and for writing in the positive vector mode. Static random access memory (SRAM) devices therefore commend themselves, but a complete field store of SRAM devices consumes a substantial amount of power and board space. Dynamic random access memory (DRAM) devices on the other hand need to be multiplexed together due to their relatively slow access time, so preventing random access. One possibility, therefore, is to use a combination of both SRAM and DRAM devices. This is possible because it is only necessary to have random access to a limited number of locations at any one time.

The maximum motion vector values are plus and minus sixteen vertically and plus and minus twenty-four horizontally. Therefore if thirty-two lines of the field are stored in SRAM devices, then random reading and writing can be performed. The rest of the field store 113 can be formed of DRAM devices to save power and board space. In the positive vector mode the 32-lines SRAM device store is positioned ahead of the remainder of the field store, that is one field minus thirty-two lines, formed of DRAM devices. Hence, it is possible to write randomly in the SRAM devices. One the other hand, in the negative vector mode, the 32-lines SRAM device store is positioned after the remainder of the field store, that is one field minus thirty-two lines, formed of DRAM devices.

Attention is drawn to seven other European patent applications, corresponding to UK patent applications 8728445, 8728446, 8728448, 8728449, 8728450, 8728451 and 8728452 relating to similar subject matter, which we filed on the same day as the present application, and the disclosures in which are incorporated herein by reference.

Claims

1. A television standards converter comprising:
means (36 to 40) for analyzing the motion between consecutive fields of an input television signal of one television standard and for deriving motion vectors in dependence on said motion;
characterized by:
means (47) recursively to filter said motion vectors;
means (1) then to align said fields in dependence on said filtered motion vectors so as effectively to represent static pictures; and
means (1) to effect conversion using said static pictures to derive the required output television signal of a different television standard.

2. A television standards converter according to claim 1 wherein said recursive filter means (47) operates such that the motion vector for a given pixel in a given field is used to point to a pixel in the preceding field, and the motion vector for said pixel in said preceding field is then recursively filtered with the motion vector for said given pixel to form the final motion vector for said given pixel in said given field.

3. A television standards converter according to claim 1 wherein said recursive filter means (47) operates such the motion vector for a given pixel in a given field is used to point to a pixel in the succeeding field, and the motion vector determined for said pixel in said succeeding field is then recursively filtered with the motion vector for said given pixel to form the final motion vector for said pixel in said given field.

4. A television standards converter according to claim 1, claim 2 or claim 3 wherein said motion vectors are derived by determining motion in said image at points spaced a predetermined number of samples horizonally and a predetermined number of samples vertically by a block matching technique.

5. A television standards converter according to claim 4 wherein said block matching technique comprises the steps of:
testing for minimum difference in three positions, the centre position of a block, a predetermined number of samples to the left, and the same predetermined number of samples to the right;
starting from the point indicated above, testing for minimum difference in nine positions symmetrically distributed about the above starting point in steps of a smaller predetermined number of samples or lines;
starting from the point indicated above, testing for

minimum difference in nine positions symmetrically distributed about the above starting point in steps of a still smaller predetermined number of samples or lines;

starting from the point indicated above, testing for minimum difference in nine positions symmetrically distributed about the above starting point in steps of a still smaller predetermined number of samples or lines; and

starting from the point indicated above, testing for minimum difference in nine positions symmetrically distributed about the above starting point in steps of one sample or line.

6. A television standards converter according to claim 5 where said block matching technique comprises a further step, subsequent to the last step of claim 5, of comparing the difference produced at the final position indicated by said last step with the two differences above and below to adjust the vertical vector value, and with the two differences to the left and right to adjust the horizontal vector value.

7. A 625-line 50-fields per second to 525-line 60-fields per second television standards converter comprising:

a first time base corrector (11) for receiving an input 625-line 50-fields per second digital television signal;

characterized by:

a motion analyzer (36 to 40) connected to the output of said first time base corrector (11) for analyzing motion in said input television signal and for deriving motion vectors in dependence on said motion; means (47) recursively to filter said motion vectors;

a shift register (12) also connected to the output of said first time base corrector (11);

an interpolator (1) for deriving samples of a required output 525-line 60-fields per second digital television signal in dependence on samples derived from said shift register (12) and said filtered motion vectors; and

a second time base corrector (18) for assembling said derived samples to form said output television signal.

8. A television standards converter according to claim 7 wherein said first time base corrector (11) is a 4-field time base corrector (11) and said second time base corrector (18) is a 2-field time base corrector (18).

9. A television standards converter according to claim 8 wherein said 4-field time base corrector (11) derives 585-line 60 fields per second television signal from said input television signal for supply to said shift register (12).

10. A 525-line 60-fields per second 625-line 50-fields per second television standards converter comprising:

a first time base converter (18) for receiving an input 525-line 60-fields per second digital television signal;

characterized by:

a motion analyzer (36 to 40) connected to the output of said first time base corrector (18) for analyzing motion in said input television signal and for deriving motion vectors in dependence on said motion vectors;

means (47) recursively to filter said motion vectors;

a shift register (12) also connected to the output of said first time base corrector (18);

an interpolator (1) for deriving samples of a required output 625-line 50-fields per second digital television signal in dependence on samples derived from said shift register (12) and said filtered motion vectors; and

a second time base corrector (11) for assembling said derived samples to form said output television signal.

11. A television standards converter according to claim 10 wherein said first time base corrector (18) is a 2-field time base corrector (18) and said second time base corrector (11) is a 4-field time base corrector (11).

12. A television standards converter according to claim 11 wherein said 2-field time base corrector (18) derives a 585-line 60-fields per second television signal from said input television signal for supply to said shift register (12).

13. A slow motion processor comprising:

an input circuit (31, 11) for receiving an input digital television signal;

a motion analyzer (36 to 40) for analyzing motion in said input digital television signal and for deriving motion vectors in dependence on said motion;

characterized by:

means (47) recursively to filter said motion vectors;

a shift register (12) for holding successive different fields of said input television signal;

an interpolator (1) for deriving samples of a required slow motion output digital television signal in dependence on the degree of slow motion, samples derived from said shift register (12), and said filtered motion vectors; and

a 2-field time base corrector (18) for assembling said derived samples to form said slow motion output television signal.

14. A slow motion processor according to claim 13 wherein said input circuit (31, 11) comprises is a 4-field time base corrector (11).

15. A slow motion processor according to claim 14 wherein said 4-field time base corrector (11) derives a 585-line 60-fields per second television signal from said input television signal for supply to said shift register (12).

Fig.1.

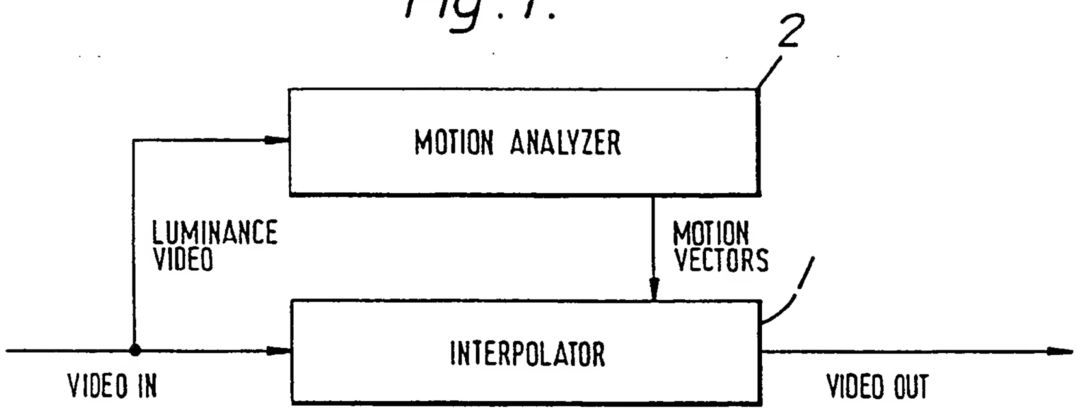

2
MOTION ANALYZER
LUMINANCE
VIDEO
MOTION
VECTORS
1
INTERPOLATOR
VIDEO IN
VIDEO OUT

Fig. 2.

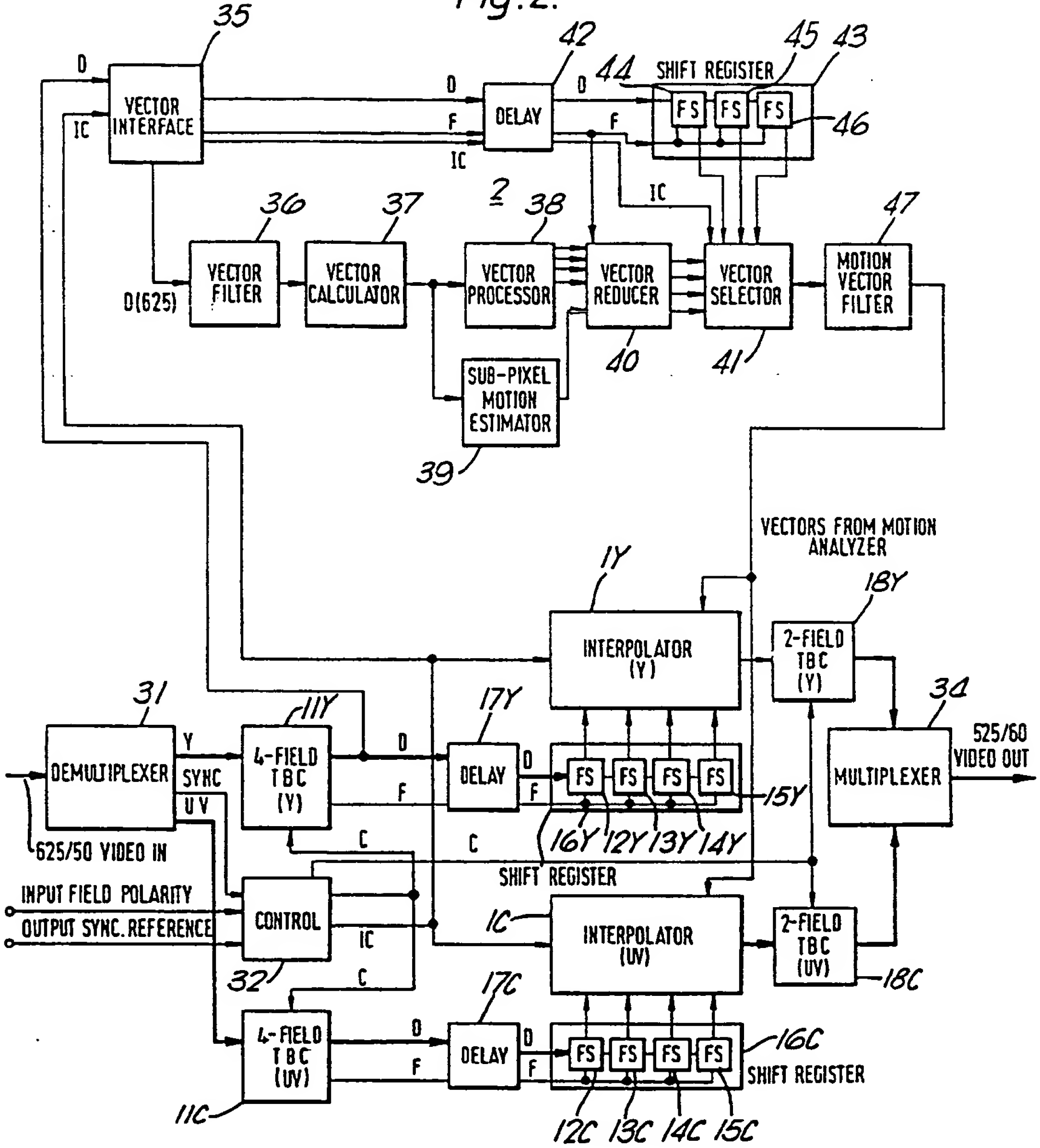

35
VECTOR INTERFACE
D
IC
42
DELAY
D
F
IC
44
SHIFT REGISTER
45
43
FS
FS
FS
46
36
VECTOR FILTER
D(625)
37
VECTOR CALCULATOR
2
38
VECTOR PROCESSOR
VECTOR REDUCER
40
VECTOR SELECTOR
41
47
MOTION VECTOR FILTER
SUB-PIXEL MOTION ESTIMATOR
39
VECTORS FROM MOTION ANALYZER
1Y
INTERPOLATOR (Y)
18Y
2-FIELD TBC (Y)
31
DEMULTIPLEXER
Y
SYNC
UV
625/50 VIDEO IN
11Y
4-FIELD TBC (Y)
17Y
DELAY
15Y
16Y 12Y 13Y 14Y
SHIFT REGISTER
34
MULTIPLEXER
525/60 VIDEO OUT
C
INPUT FIELD POLARITY
OUTPUT SYNC. REFERENCE
CONTROL
32
1C
INTERPOLATOR (UV)
2-FIELD TBC (UV)
18C
17C
4-FIELD TBC (UV)
11C
16C
SHIFT REGISTER
12C 13C 14C 15C

Fig.3.

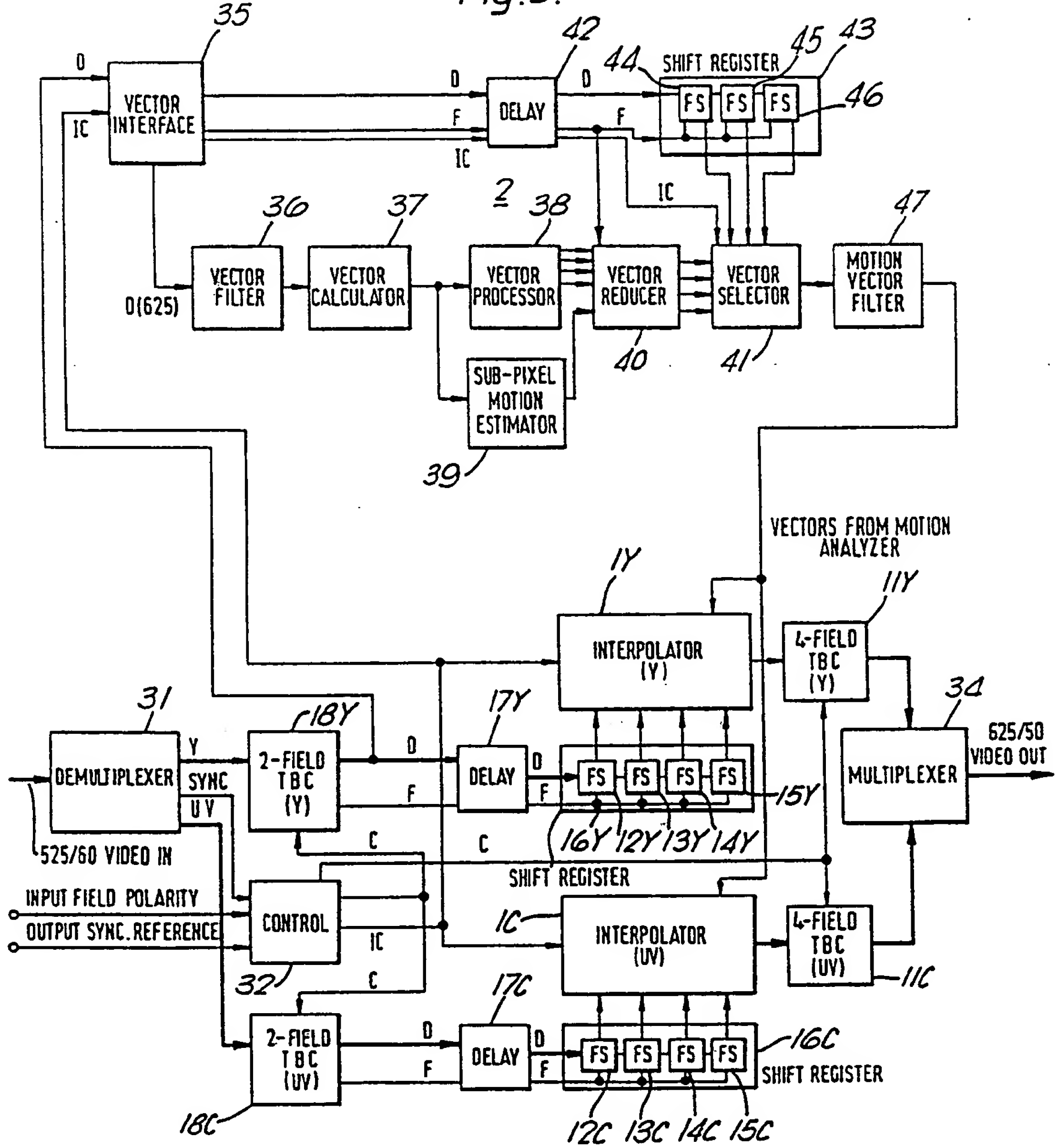
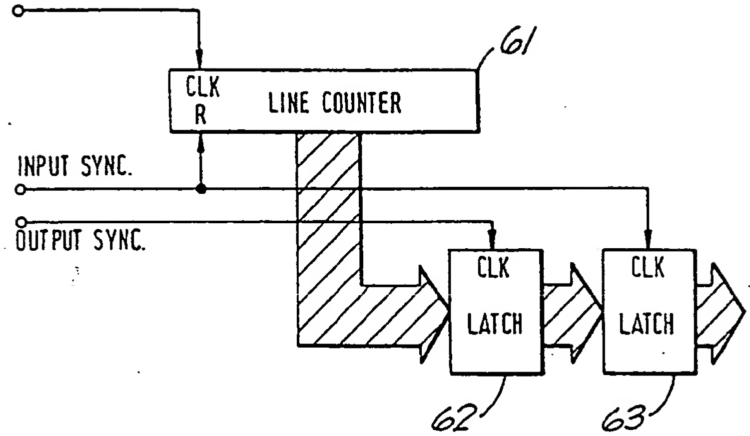

VECTOR INTERFACE
DELAY
SHIFT REGISTER
FS
VECTOR FILTER
VECTOR CALCULATOR
VECTOR PROCESSOR
VECTOR REDUCER
VECTOR SELECTOR
MOTION VECTOR FILTER
SUB-PIXEL MOTION ESTIMATOR
D(625)
VECTORS FROM MOTION ANALYZER
INTERPOLATOR (Y)
4-FIELD TBC (Y)
DEMULTIPLEXER
2-FIELD TBC (Y)
MULTIPLEXER
625/50 VIDEO OUT
525/60 VIDEO IN
INPUT FIELD POLARITY
OUTPUT SYNC. REFERENCE
CONTROL
INTERPOLATOR (UV)
4-FIELD TBC (UV)
2-FIELD TBC (UV)
SYNC
UV
IC

Fig.4.



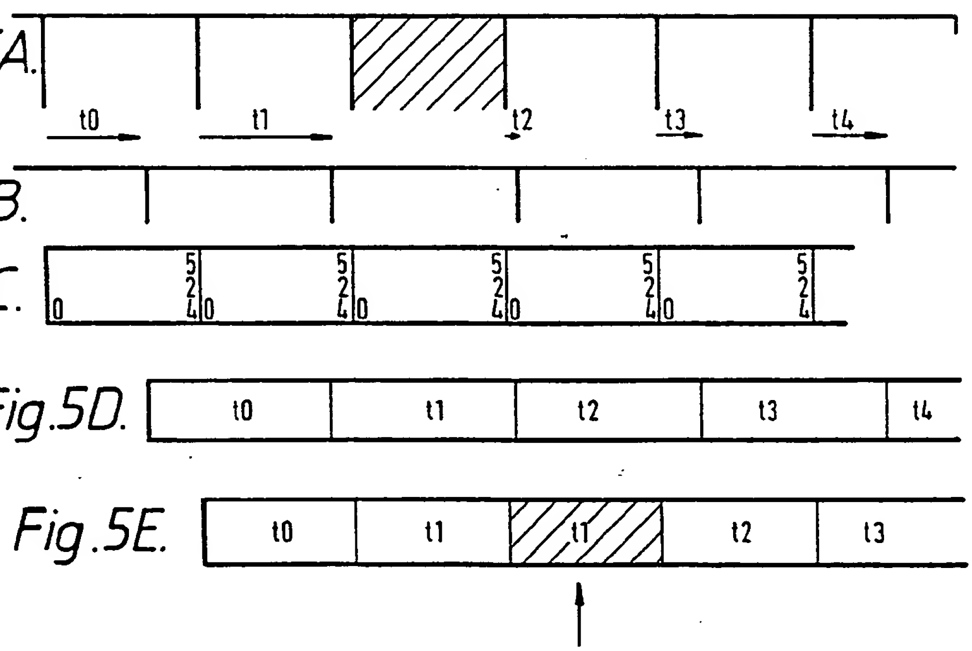


Fig.5A.

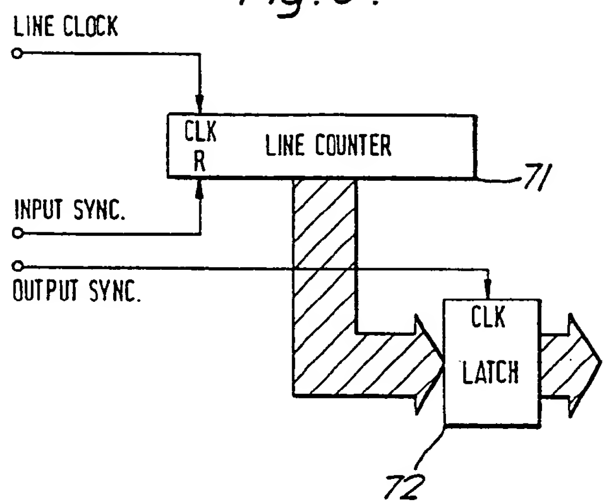
Fig.5B.

Fig.5C.

Fig.5D.

Fig.5E.

Fig. 6.


LINE CLOCK
CLK
R
LINE COUNTER
71
INPUT SYNC.
OUTPUT SYNC.
CLK
LATCH
72

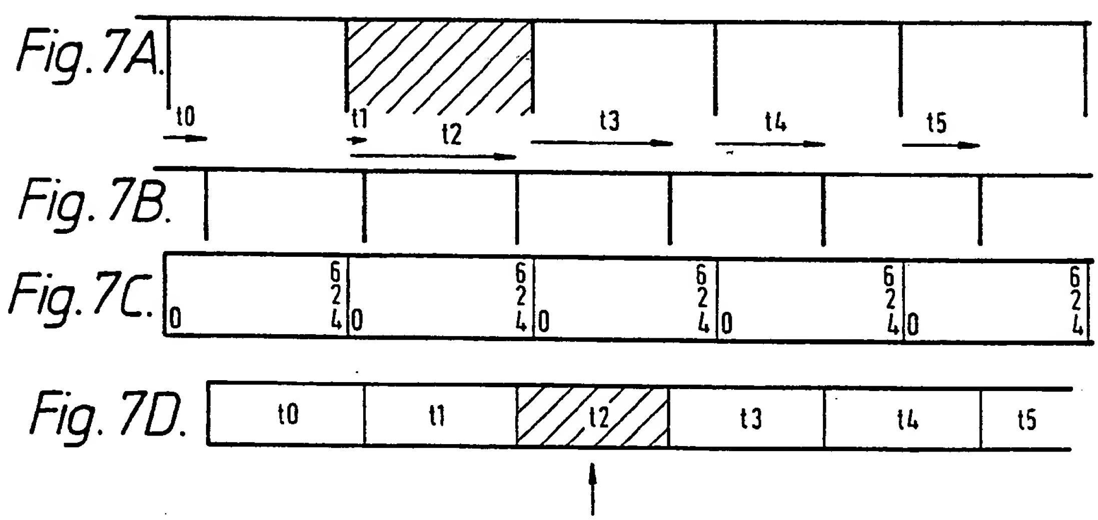
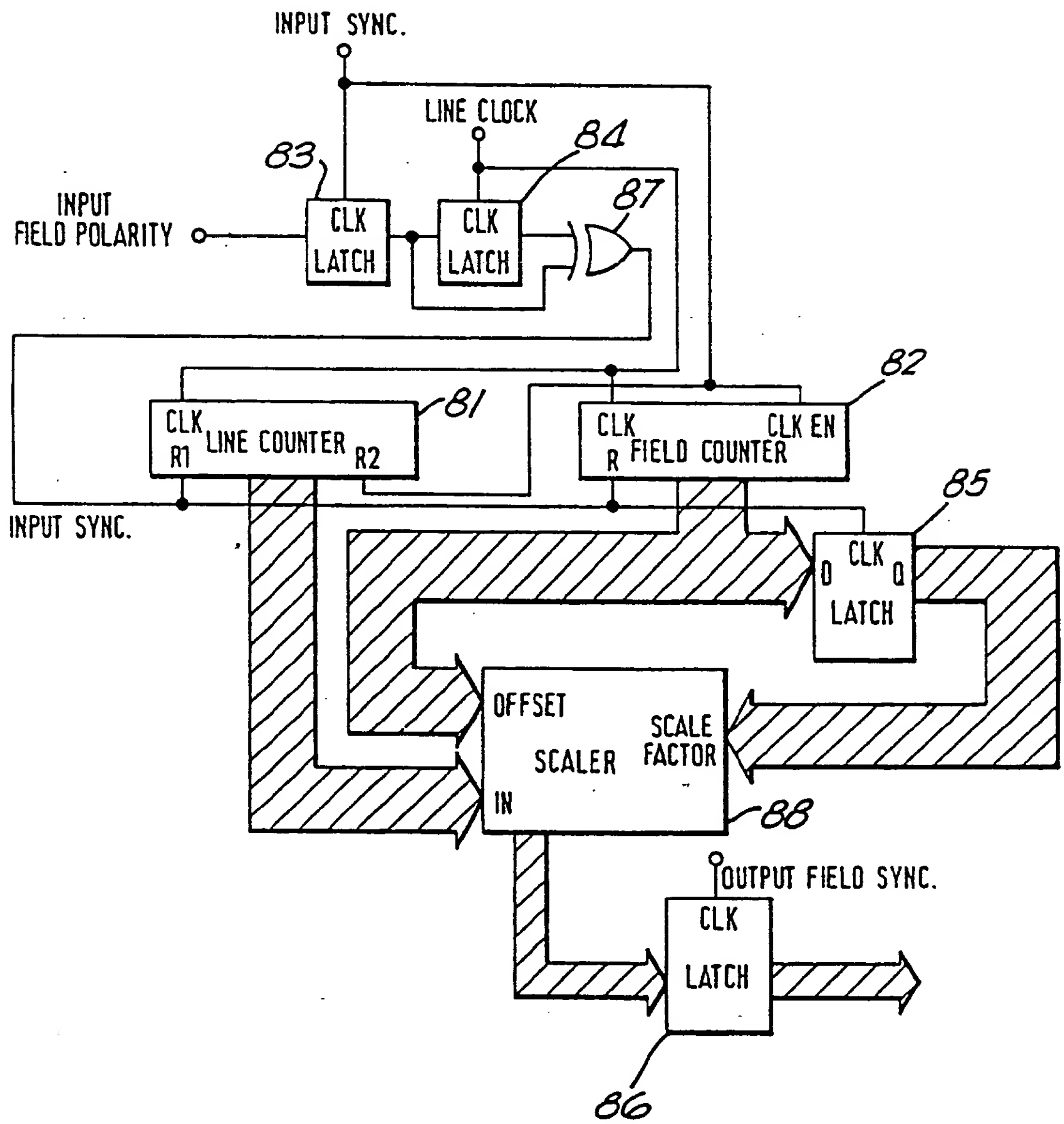


Fig. 7A.
t0
t1
t2
t3
t4
t5
Fig. 7B.
Fig. 7C.
0
624
0
624
0
624
0
624
0
624
Fig. 7D.
t0
t1
t2
t3
t4
t5

Fig. 8.



INPUT SYNC.
LINE CLOCK
83
84
87
INPUT
FIELD POLARITY
CLK
LATCH
CLK
LATCH
82
81
CLK
LINE COUNTER
R1
R2
CLK
CLK EN
R
FIELD COUNTER
INPUT SYNC.
85
CLK
D
Q
LATCH
OFFSET
SCALER
SCALE
FACTOR
IN
88
OUTPUT FIELD SYNC.
CLK
LATCH
86

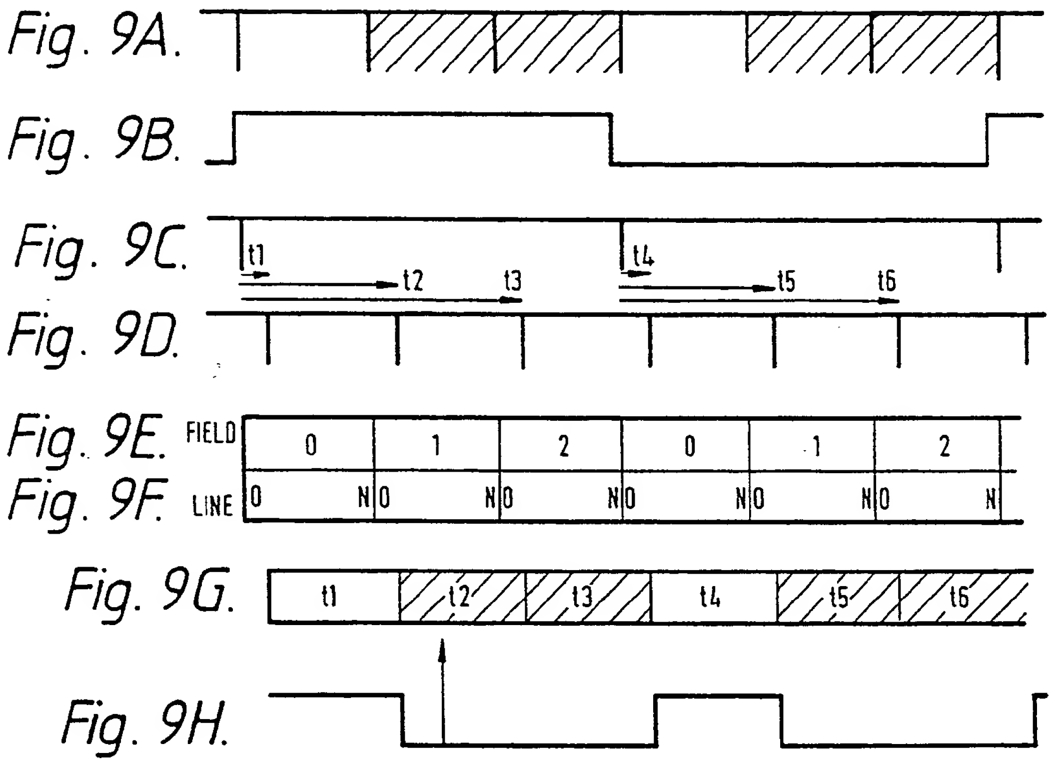
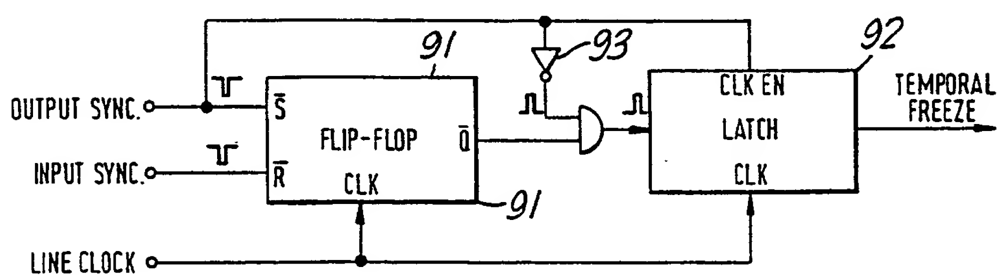


Fig. 9A.
Fig. 9B.
Fig. 9C.
t1
t2
t3
t4
t5
t6
Fig. 9D.
Fig. 9E.
FIELD
0
1
2
0
1
2
Fig. 9F.
LINE
0
N
0
N
0
N
0
N
0
N
0
N
Fig. 9G.
t1
t2
t3
t4
t5
t6
Fig. 9H.

Fig. 10.


OUTPUT SYNC.
INPUT SYNC.
LINE CLOCK
91
$\bar{S}$
FLIP-FLOP
$\bar{Q}$
$\bar{R}$
CLK
91
93
92
CLK EN
LATCH
CLK
TEMPORAL
FREEZE

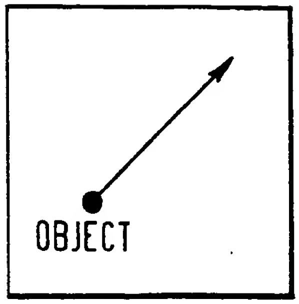


FIG.11A.

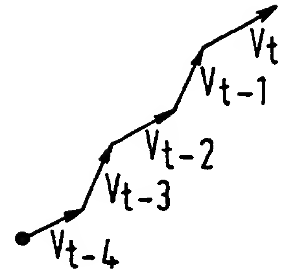


FIG.11B.

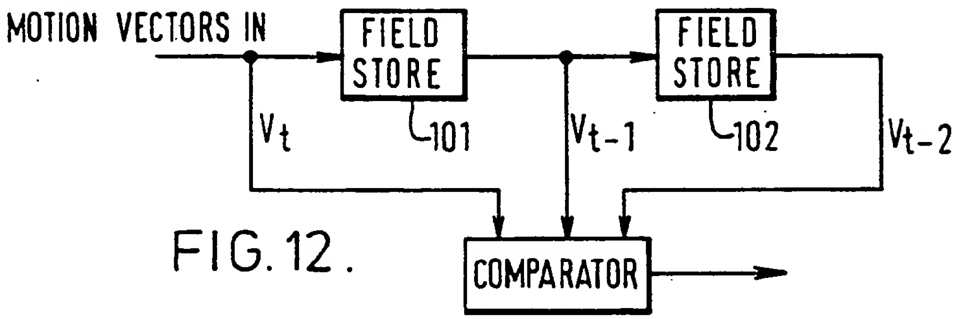


FIG.12.

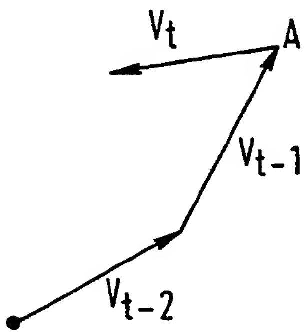


FIG.13.

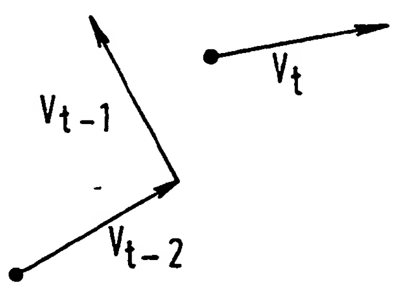


FIG.14.

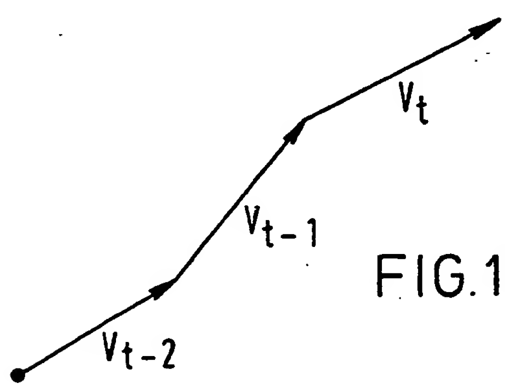


FIG.15.

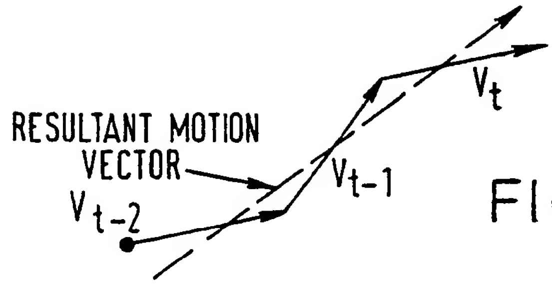


FIG. 16.

FIG. 17.

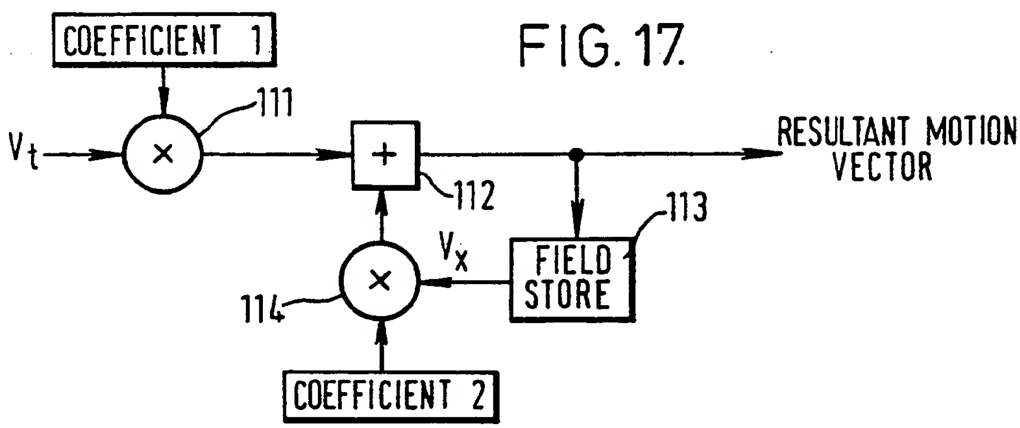
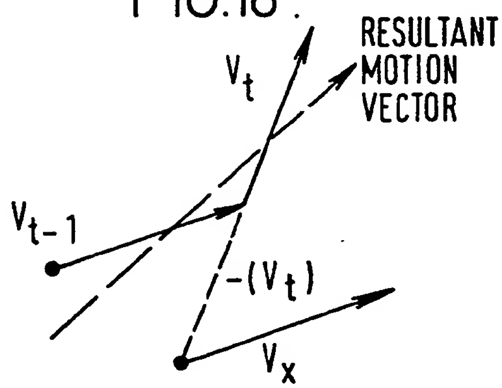


FIG. 18.



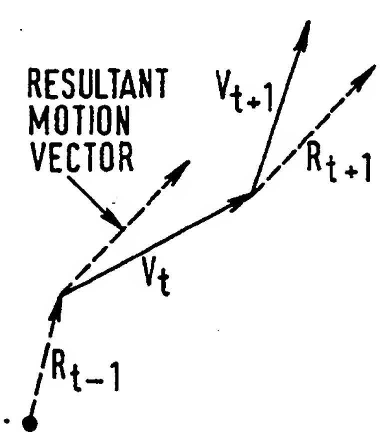


FIG. 20.

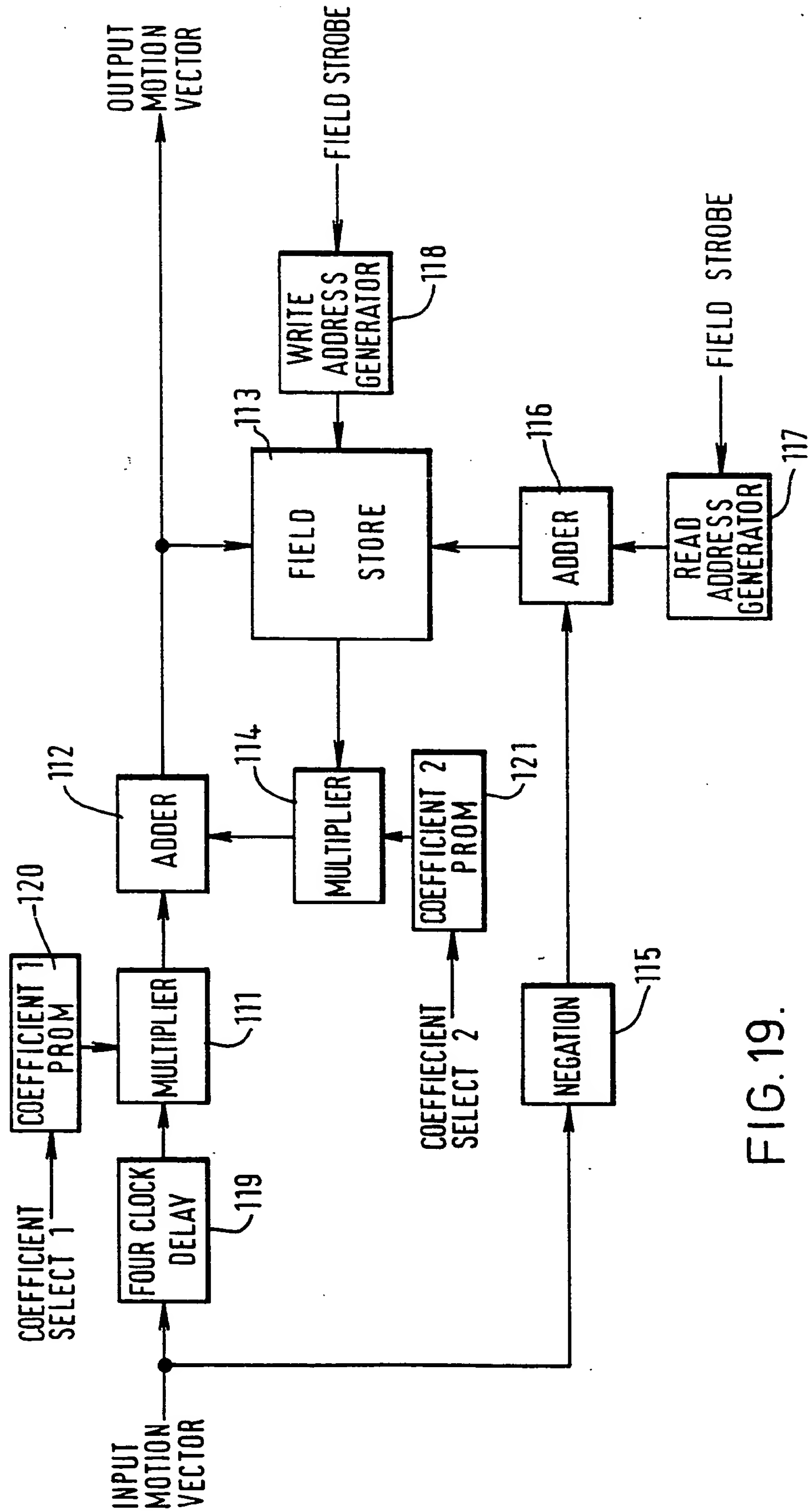

OUTPUT MOTION VECTOR
FIELD STROBE
WRITE ADDRESS GENERATOR
118
113
FIELD STORE
116
ADDER
FIELD STROBE
117
READ ADDRESS GENERATOR
112
ADDER
114
MULTIPLIER
COEFFICIENT 2 PROM
121
120
COEFFICIENT 1 PROM
MULTIPLIER
111
COEFFECIENT SELECT 2
NEGATION
115
COEFFICIENT SELECT 1
FOUR CLOCK DELAY
119
INPUT MOTION VECTOR

FIG. 19.

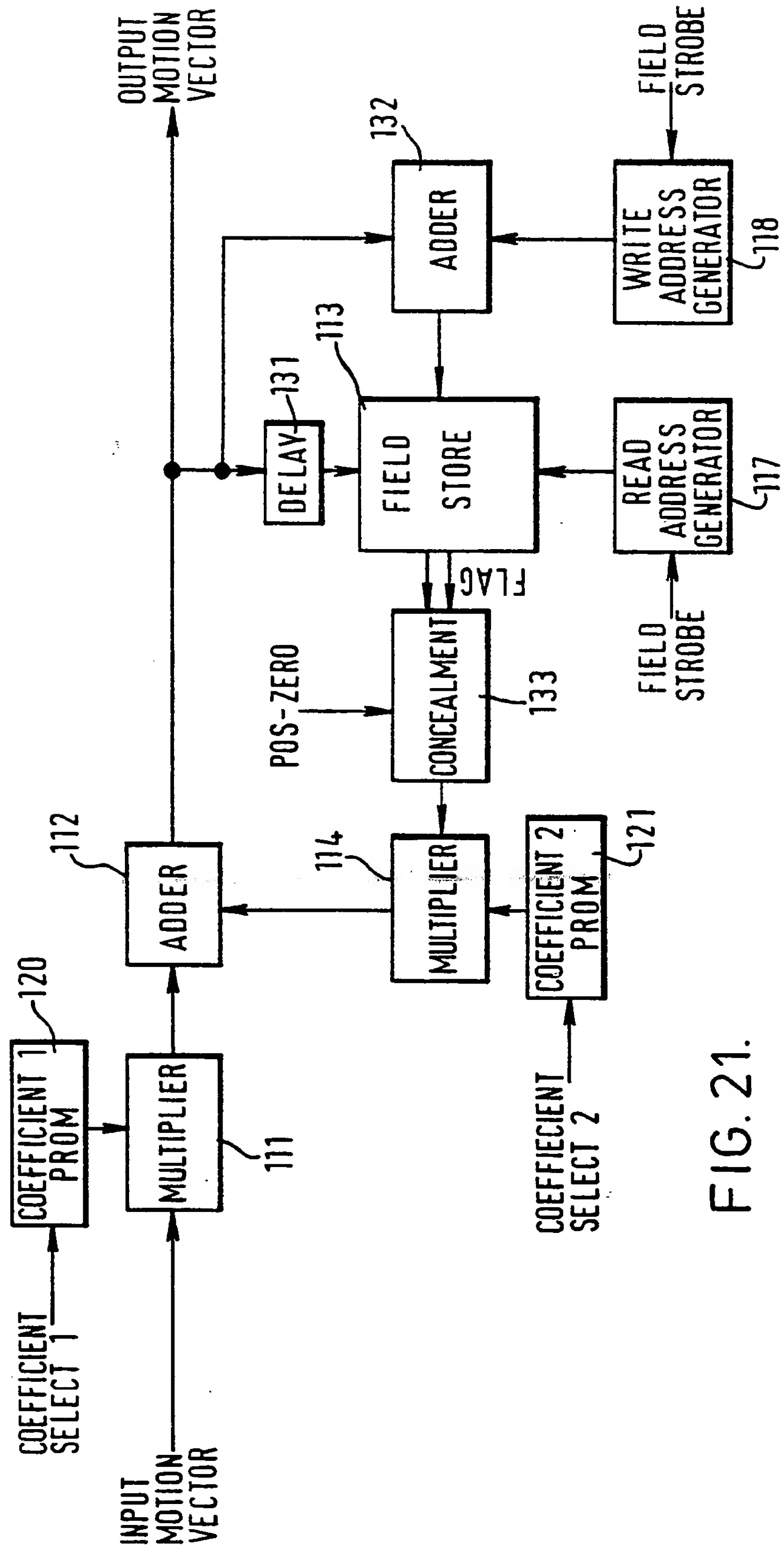

OUTPUT MOTION VECTOR
INPUT MOTION VECTOR
COEFFICIENT SELECT 1
COEFFICIENT 1 PROM
120
MULTIPLIER
111
ADDER
112
DELAY
131
FIELD STORE
113
ADDER
132
WRITE ADDRESS GENERATOR
118
FIELD STROBE
READ ADDRESS GENERATOR
117
FIELD STROBE
FLAG
CONCEALMENT
133
POS-ZERO
MULTIPLIER
114
COEFFICIENT 2 PROM
121
COEFFIECIENT SELECT 2

FIG. 21.

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Office européen des brevets

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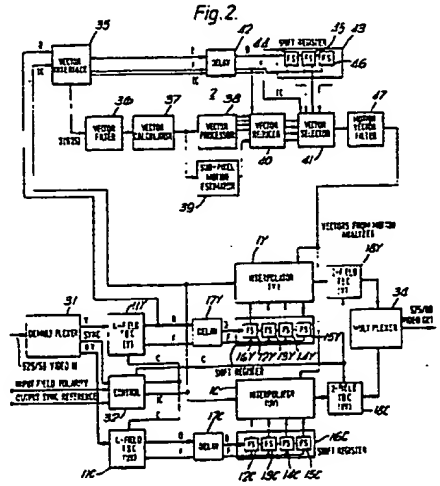
(54) Motion vector processing in digital television images.

(57) A television standards converter comprises a motion analyzer (36 to 40) for analyzing the motion between consecutive fields of an input television signal of one television standard and for deriving motion vectors in dependence on the motion, a filter (47) for recursively filtering the motion vectors, and an interpolator (1) for aligning the fields in dependence on the filtered motion vectors so as effectively to represent static pictures, and means (1) to effect conversion using the static pictures to derive the required output television signal of a different television standard.

Fig.2.



EP 0 294 957 A3

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 88 30 4615

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
Y	NHK LABORATORIES NOTE, no. 326, January 1986, pages 1-15, Tokyo, JP; Y. TANAKA et al.: "HDTV-PAL standards converter" * Page 7, line 15 - page 15, line 10 *	1	H 04 N 7/01 H 04 N 9/89
Y	US-A-4 661 849 (B.L. HINMAN) * Figures 5-8; column 8, lines 6-28 *	1,7,10	
A Y	GB-A-2 162 018 (KOKUSAI DENSHIN DENWA) * Abstract; figures *	2,3,13 7,10	
A Y	NHK TECHNICAL MONOGRAPH, no. 17, March 1971, pages 3-37; H. SAKATA et al.: "Television standards converter" * Page 5, left-hand column, line 9 - page 15, right-hand column, line 8 *	1 7.10	
A		8,9,11,12,14,15	
A	WO-A-8 502 080 (IBA) * Abstract; figures 4,7 *	2,3	
A	INTERNATIONAL CONFERENCE ON COMMUNICATIONS'86, Toronto, 22nd - 26th June 1986, vol. 2, pages 1280-1284, IEEE, New York, US; Y. NINOMIYA et al.: "A motion vector detector for muse encoder" * Page 1280, right-hand column, line 20 - page 1281, left-hand column, line 8; figures 1,8 *	4	
A	DE-A-3 613 230 (MITSUBISHI DENKI K.K.) * Page 12, lines 1-23; page 15, line 1 - page 16 *	13	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

H 04 N
G 06 F

The present search report has been drawn up for all claims

Place of search	Date of completion of search	Examiner
The Hague	02 November 90	BOSCH F.M.D.

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